10 actg
~~~~
~~~~ 11

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: November 28, 1977

Project Title: Conservation of Water, Energy, and Chemicals in Dyeing Nylon Carpets

Project No: E-27-660

Project Director: Professor Wayne Tincher

Sponsor: U.S. Department of the Interior, OWRT

Agreement Period: From 9/28/77 Until 1/30/78

Type Agreement: Letter dated 9/28/77

Amount: $1,850 (Fixed Price)

Reports Required: Final Report

Sponsor Contact Person (s):

Technical Matters

Contractual Matters
(thru OCA)

Jack C. Jorgensen
U.S. Department of Interior
Office of Water Research and Technology
Washington, D. C. 20240

Defense Priority Rating: none

Assigned to: Textile Engineering (School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director—EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA)

Library, Technical Reports Section
Office of Computing Services
Director, Physical Plant
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other

CA—3 (3/76)

no action

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 2/13/78

Project Title: Conservation of Water, Energy and Chemicals in Dyeing Nylon Carpets

Project No: E-27-660

Project Director: Dr. W. C. Tincher

Sponsor: Office of Water Research and Technology (OWRT)

Effective Termination Date: 1/30/78 (Fixed Price)

Clearance of Accounting Charges: 1/30/78

Grant/Contract Closeout Actions Remaining:

X Final Invoice ~~and Closing Documents~~
_ Final Fiscal Report
_ Final Report of Inventions
_ Govt. Property Inventory & Related Certificate
_ Classified Material Certificate
_ Other ______

Assigned to: Textile Engineering (School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director—EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA)
Library, Technical Reports Section
Office of Computing Services
Director, Physical Plant
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other ______

CA-4 (3/76)

E-27-660
Final

WATER RESEARCH CAPSULE REPORT

Conservation of Water, Chemicals, and Energy in Dyeing Nylon Carpet

Technology Transfer
Office of Water Research and Technology
U.S. Department of the Interior

WATER RESEARCH CAPSULE REPORT

Conservation of Water, Chemicals, and Energy
in Dyeing Nylon Carpet

SUGGESTED FORMAT

(Numbers refer to photographs)

Front Cover
Nos. 1,2,3

Inside Front Cover
No. 4

Page 1
Foreword
No. 5 or 6

Pages 2 and 3
Significance
Nos. 7,8,9

Pages 4 and 5
The Proposed Process Modification
Nos. 10,11,12

Pages 6 and 7
Dyeing
Nos. 13,14,15

Page 8
Advantages of the Reuse System
Table - Potential Materials Reduction for a Typical Beck Dyeing Process Load

Page 9
Other Application
Nos. 16,17

FOREWORD

The availability of large quantities of high quality water is an important prerequisite for industrial development. United States industry, for example, uses approximately 43 trillion gallons of water annually. The abundance of water in the United States and its low cost have permitted relatively indiscriminant use of water by industry. Processes have been developed and equipment has been designed with little or no consideration of the quantity of water required or the efficiency of water use. As population and industrial activity increase, this approach to water use must be changed. Development of industrial processes with water use requirements as an important design parameter is essential from both environmental and economic considerations.

This capsule report demonstrates how one industry can reduce its water consumption by process modification. In addition to reduction in water use, a substantial reduction in energy and chemical requirements can be achieved by the process changes.

The findings reported here were the result of a research project funded by the Office of Water Research and Technology (OWRT), U.S. Department of the Interior, through the Environmental Resources Center and undertaken in the School of Textile Engineering of the Georgia Institute of Technology.

THE SIGNIFICANCE

Textile manufacturing is a major industry in the United States. It is heavily concentrated in southeastern United States and places a significant burden on the water supply and waste treatment facilities of this region. Over 425 billion gallons of water are used annually.

Carpet production is one of the most rapidly growing segments of the textile industry. The development of the tufting process in the 1950's coupled with the availability of low cost synthetic fibers has placed carpet within reach of almost every home, apartment and office building in the United States. Carpet production in 1976 was valued in excess of 3.5 billion dollars.

Carpet manufacturing requires large quantities of water, energy and chemicals, particularly in the dyeing operation. It is estimated that 18 gallons of water are required for each square yard of carpet produced. Dyeing of one square yard also requires 30,000 BTU's of energy and approximately 0.15 pounds of various chemicals. The load on waste treatment plants due to carpet wastewater is substantial. A typical carpet dyeing facility will discharge between 1 and 2 million gallons of wastewater per day.

Reduction in the requirement for water, energy and chemicals has been achieved by the process changes in carpet beck dyeing that are described here. Instead of discharging the dyebath following each dye cycle according to the traditional process, the spent bath is analyzed, reconstituted to the desired concentration of dyes and auxiliary chemicals, and reused. Compared with conventional carpet beck dyeing, 5 cycles of the modified procedure make possible reductions of

64% in chemical requirements
70% in water requirements
20% in energy requirements.

Color uniformity, color reproducibility and color stability of carpet dyed in the modified process are comparable to current commercial carpet production.

THE PROPOSED PROCESS MODIFICATION

In the typical beck dyeing process, the undyed carpet is placed in a large stainless steel vat or beck that is filled with cold water. A typical load consists of 100 yards of a 12 or 15 foot wide carpet (weighing about 1,000 pounds) with a liquor ratio of 20 or 30 to 1 (about 3,000 gallons of water). Dyes, dyeing assistants and pH control agents are added to the beck cold and the temperature is raised to the boil at 2-3^{o}F per min. by steam sparging. The temperature is held at 200-210^{o}F for approximately one hour to complete the dyeing process. The carpet is checked for shade and additional dye is added if necessary to produce the desired color. The dyebath is then discharged to the sewer and the carpet is rinsed. After the carpet is removed from the beck, the process is repeated with a second carpet.

The major changes that occur during the dyeing are the transfer of dye from bath to carpet and an increase in temperature from ambient to the boil. The dyeing assistants, pH control agents, and water are essentially unchanged by the dyeing process. It should be possible, therefore, to analyze the bath following the dyeing cycle and to determine the quantities of dyes that must be added to reconstitute the bath to the desired concentrations for a subsequent dyeing.

The advantages of dyebath reuse in this way are immediately obvious. First, a great reduction in the quantity of water required for subsequent dyeings should be realized owing to reuse of water in the dyebath. Second, a significant reduction in the total quantity of chemicals required for dyeing is possible owing to reuse of the dyeing assistants and pH control chemicals. These two factors in combination should greatly reduce the load on waste treatment facilities. Third, the reuse of the bath means that each dye cycle need no longer start at room temperature and the bath then be heated to the boil. Beginning the cycle at a suitable elevated temperature, 160° - 180° F for example, would greatly reduce the energy required for carpet beck dyeing.

This new dyeing procedure requires a rapid and reliable technique for analyzing dyebaths for residual dyes. The concentration of dyes in the bath is determined with a simple spectrophotometer by utilizing the light absorption properties of colored materials. The absorbance of a species is expressed by

$$A = \log \frac{I_o}{I} = K \cdot C$$

where A is the absorbance of the dye, I_o is the intensity of the light before absorption, I is the intensity of light transmitted through this system, K is a constant for the particular dye at a given wavelength and C is the dye concentration. In mixtures of dyes, the absorbance of light at a given wavelength is the sum of the absorbances of each of the dyes at that wavelength:

$$A = A_1 + A_2 + A_3 + \ldots.$$

and

$$A = K_1C_1 + K_2C_2 + K_3C_3 \ldots.$$

The K values for each dye of interest can be determined from the absorbance of known concentrations of that dye. By measuring the absorbance of mixtures of 3 dyes at unknown concentrations at 3 wavelengths (λ_1, λ_2, and λ_3), the concentrations may be found by solution of the three linear equations:

$$A_1 = K_{1\lambda_1} C_1 + K_{2\lambda_1} C_2 + K_{3\lambda_1} C_3$$

$$A_2 = K_{1\lambda_2} C_1 + K_{2\lambda_2} C_2 + K_{3\lambda_2} C_3$$

$$A_3 = K_{1\lambda_3} C_1 + K_{2\lambda_3} C_2 + K_{3\lambda_3} C_3.$$

From the volume of the residual dyebath and the concentrations of the dyes, the quantities of each dye present are determined to calculate the amount that will be added for the next dyeing.

Precise analysis for the chemicals other than dyes in the bath is not necessary. The quantity removed with the carpet can be estimated to add the appropriate amounts required for the next dyeing.

DYEING

The modified dyeing procedure has been used in the laboratory to dye nylon carpet with the two major classes of dyes -- acid and disperse--that are used. In the first experiment, nylon carpet was dyed to the same shade 5 times with acid dyes before dumping the dye bath. In the second experiment nylon carpet was dyed to 10 different colors using disperse dyes in the same dyebath. Examination of the dyed carpet both visually and with color measuring instruments showed color uniformity and color reproducibility comparable to carpet dyed by the conventional process. The color stability ("fastness") of the carpets dyed by recycle on exposure to rubbing, water, and light, was also essentially identical to conventionally dyed carpets.

Dyeings were performed on pilot scale equipment capable of dyeing carpet samples up to 4' in width. Thirty pound nylon carpet samples were dyed to the same green shade 5 times with disperse dyes before discharging the bath. Color uniformity and reproducibility of the pilot scale dyeing were excellent. The dyed samples were examined visually by the head dyers at five different plants and all agreed that the dyeings were of first quality.

In-plant demonstrations of carpet dyeing with reuse of the dye bath are now underway. In these dyeings, the dyebath is pumped to a holding tank at the end of the dyeing portion of the cycle and the carpet that has just been dyed is rinsed in the usual manner. The carpet is removed from the beck and the rinse water left in the beck. This rinse water is used to give the next carpet a short prescour to remove finish oils and polymer residue. The rinse bath is then dropped and the reconstituted dyebath returned from the holding tank for the next dyeing cycle. The bath will be reused for up to 10 dyeings before dumping.

ADVANTAGES OF THE REUSE SYSTEM

Based on the pilot scale dyeings of carpet samples five times in the reconstituted dyebath, a comparison of costs and resource requirements for conventional and reuse dyeings has been made. These materials and energy cost savings do not include the effect of increased productivity possible with the reuse system. Beginning the dyeing at 175^{o}F reduces the time that the carpet must be in the beck by eliminating the 3^{o}F per min. heat-up from 60^{o}F to 175^{o}F. Thus, a larger volume of carpet can be dyed in the same equipment per unit time.

Capital costs for conversion to the reuse system are modest. The spectrophotometer and desk-top computer required for the analytical procedure cost approximately $6000. This cost can be reduced by 50% or more if a time sharing computer system is already in use in the dyehouse. Typical color measuring equipment in use in some dyehouses can be easily modified to perform the dyebath analyses. In addition to the analytical equipment, a pump and holding tank are required. Some textile plants already have surplus equipment for these purposes.

OTHER APPLICATION

The developed techniques can be applied to other batch dyeing processes. They have been applied to dyeing women's nylon hosiery and polyester yarn packages with reuse of the dyebath for up to 10 dyeings. Pilot scale dyeing with the reuse system gave first quality products with substantial reductions in materials and energy requirements. The savings are:

	Nylon Hosiery (10 dyeings)	Polyester yarn packages (9 dyeings)
Dye cost	5 %	2%
Auxiliary chemical cost	86%	82%
Water	90%	81%
Energy	35%	42%

These experiments suggest that dyebath reuse may be applicable to all types of batch dyeing processes. These processes are currently used in dyeing of approximately 5 billion pounds of fiber each year and are very inefficient in energy and materials utilization.

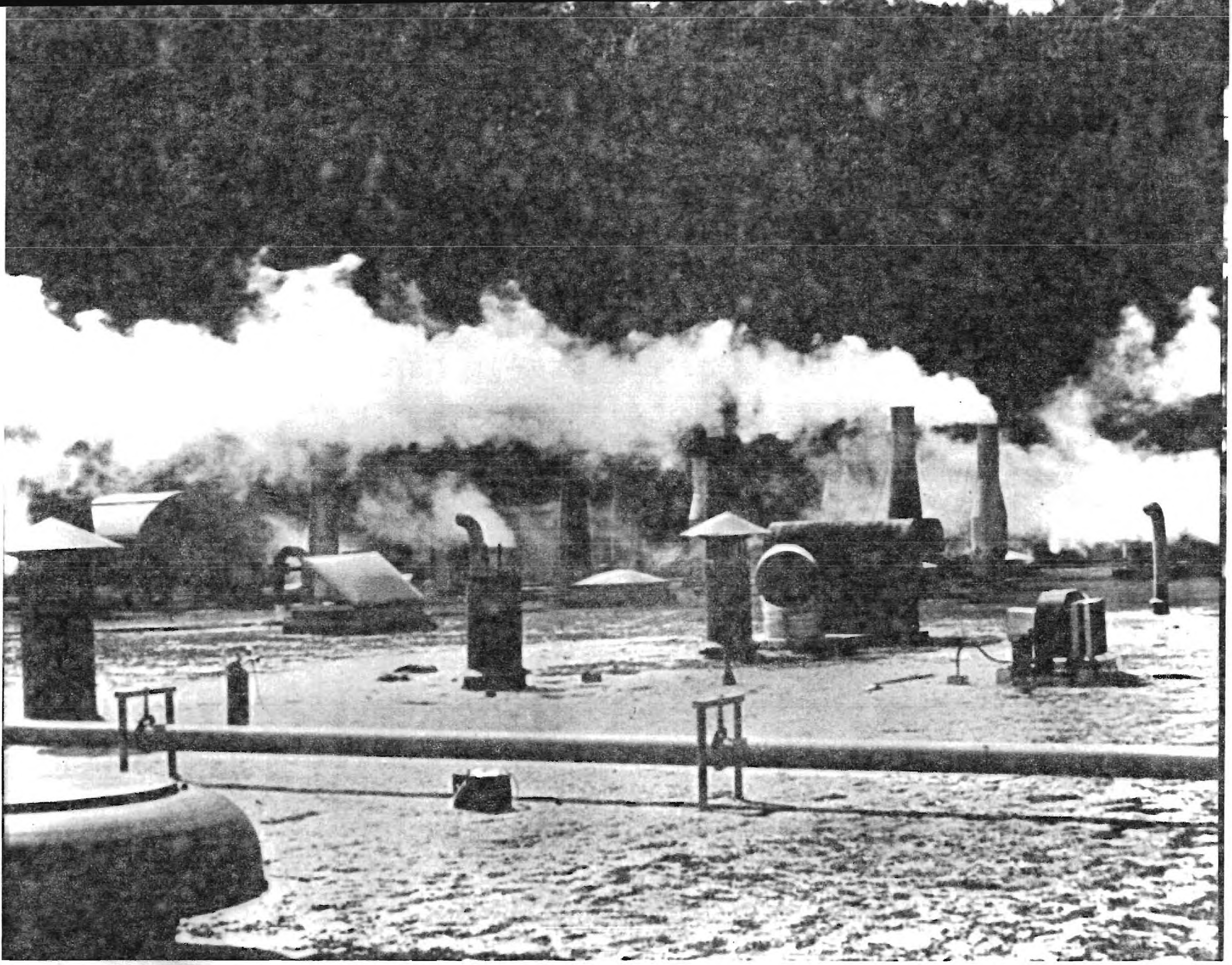
TABLE 1

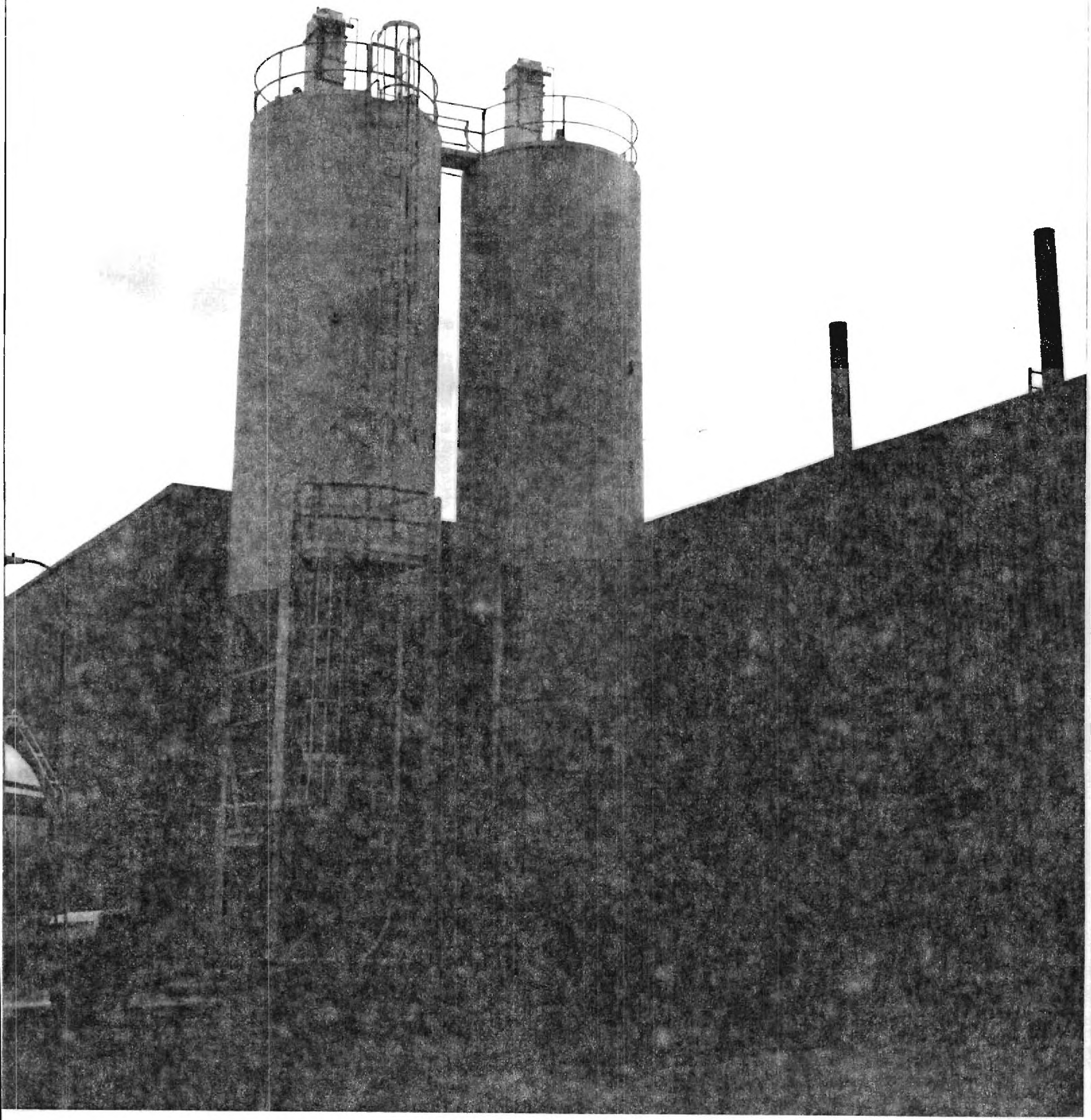
Potential Materials Reduction for a Typical
Beck Dyeing Process Load

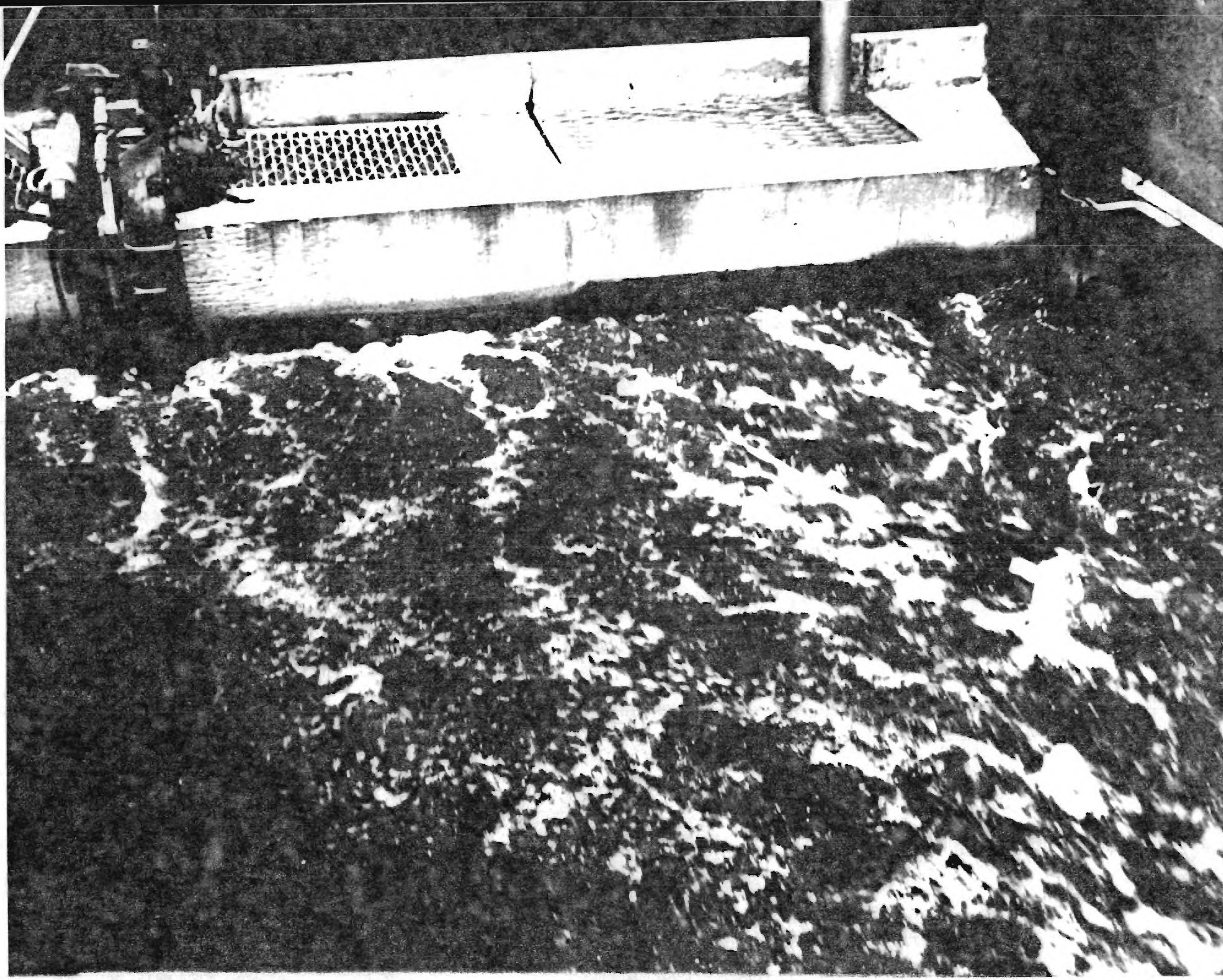
Materials	Existing Process	Modified Process	Reduction %
Carpet			
Square yards	500	same	
Weight (pounds)	1000	same	
Water (gallons)	3000	900	70
Energy (BTU's)	10,000,000	8,000,000	20
Chemicals (pounds)	25	9	64
Chemical & Energy cost($)	43	29	33

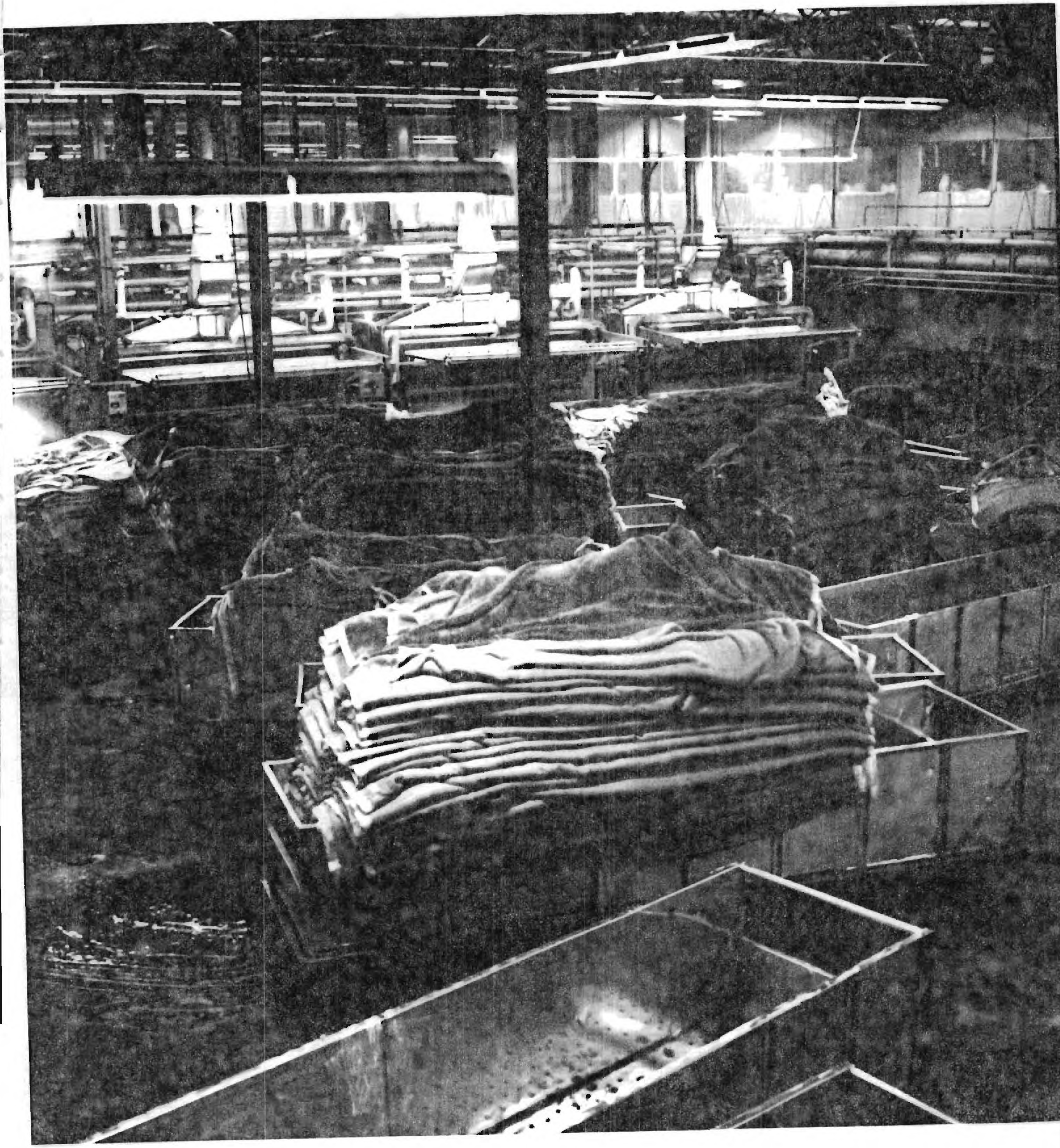
Notes: 1. Values scaled up linearly from pilot scale dyeing of carpet samples (dyeing phase only) five times in the reconstituted dye bath.

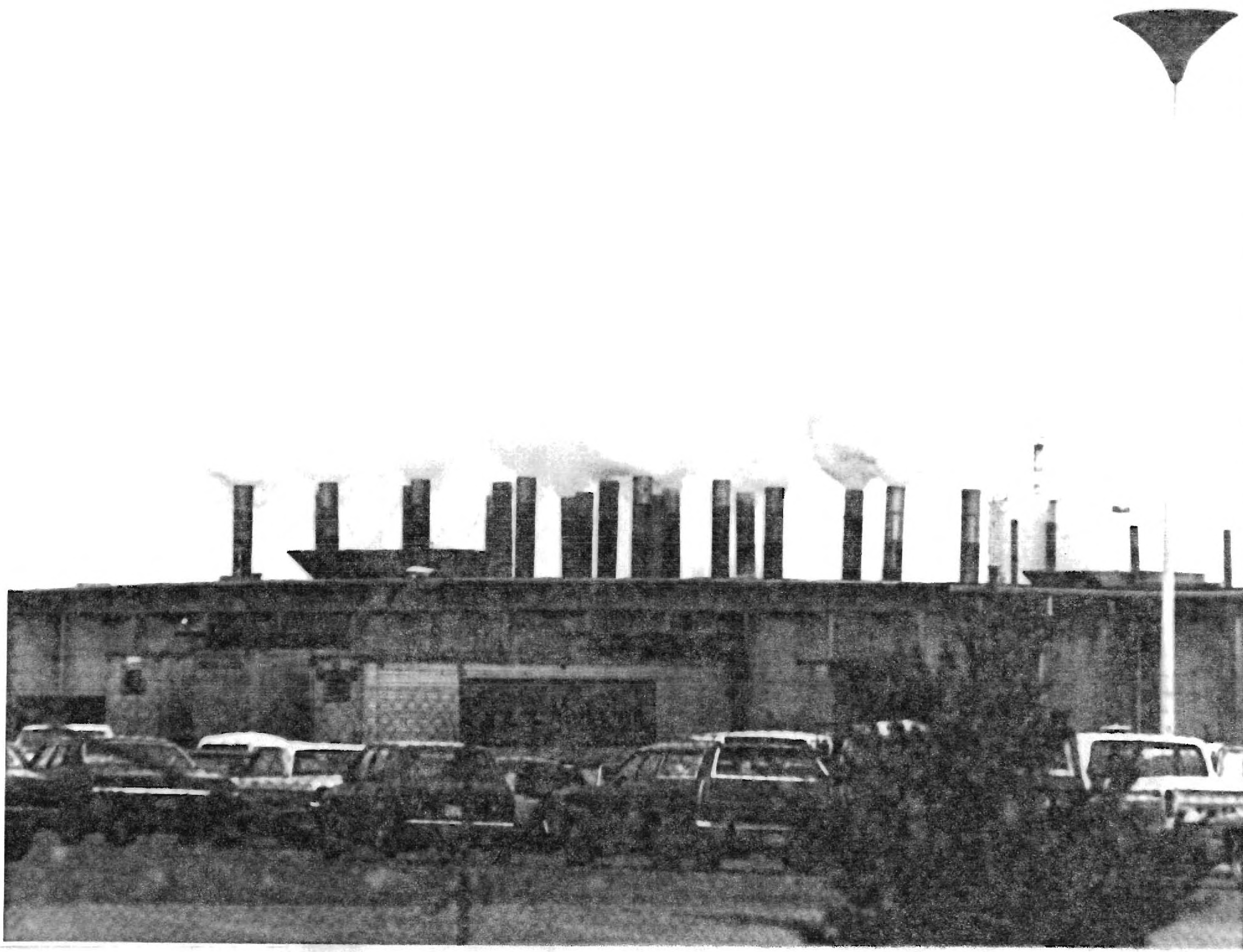
2. Cost savings from chemical and energy reductions are in addition to those savings expected from increased productivity that is possible with the reuse system.

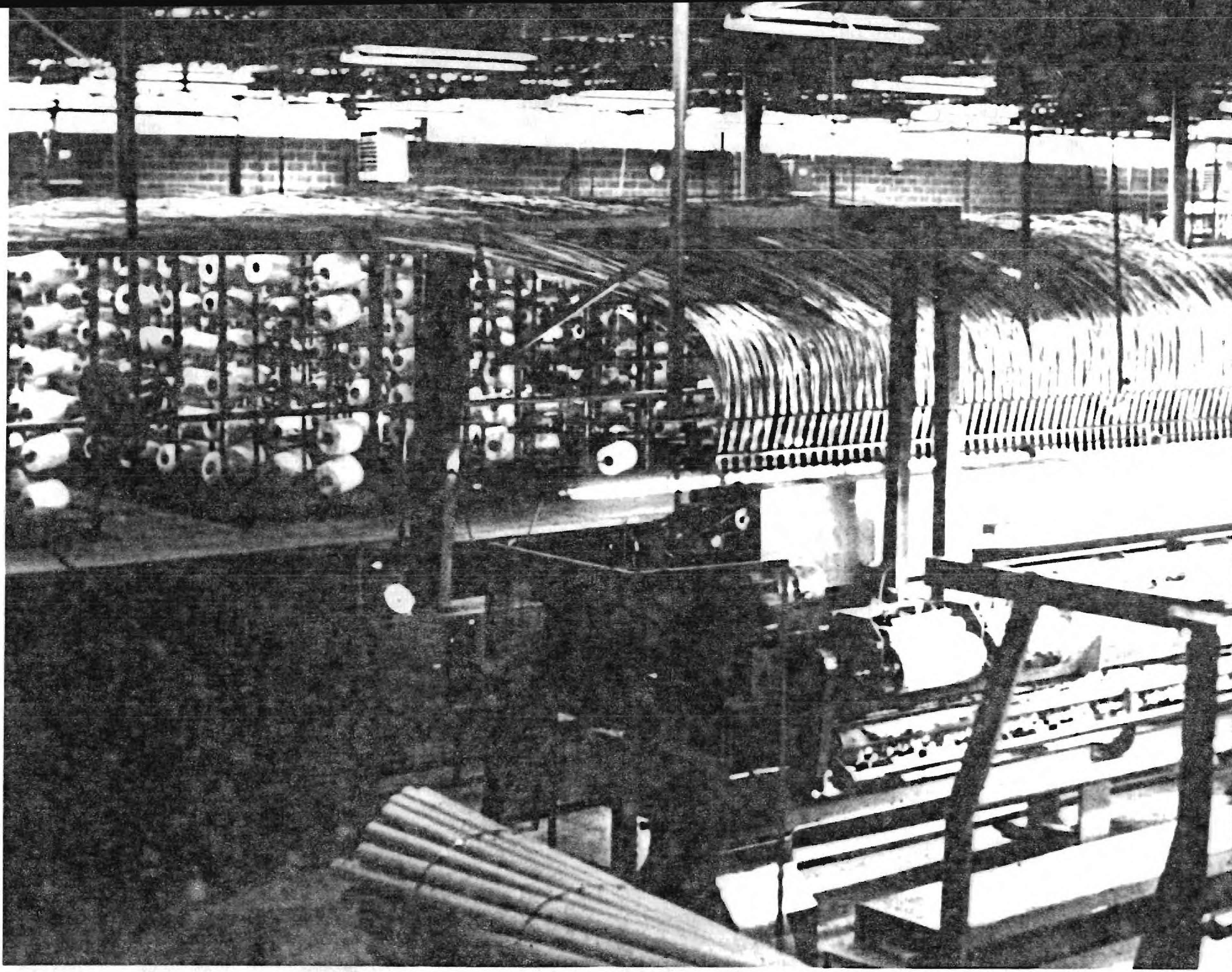


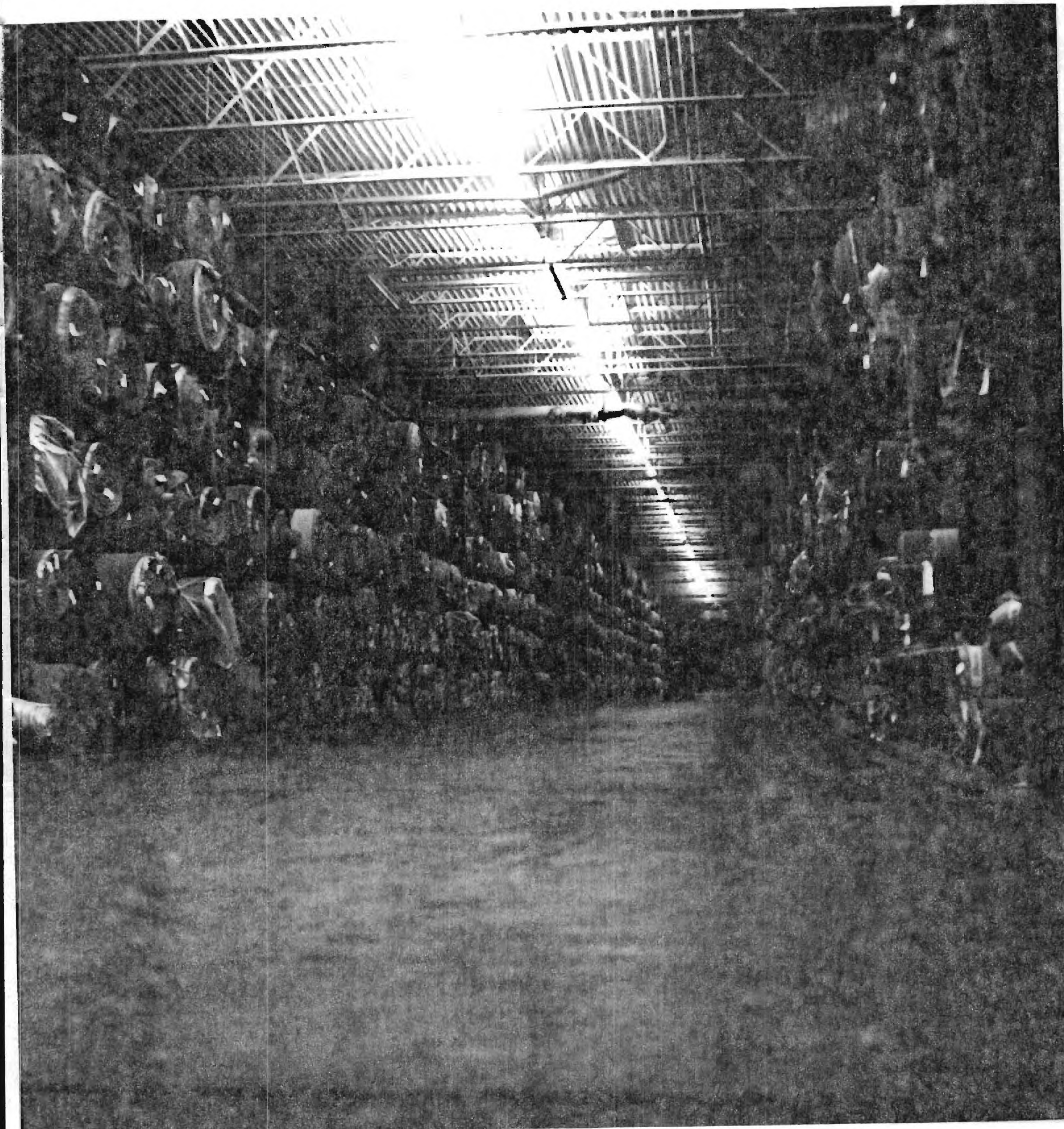




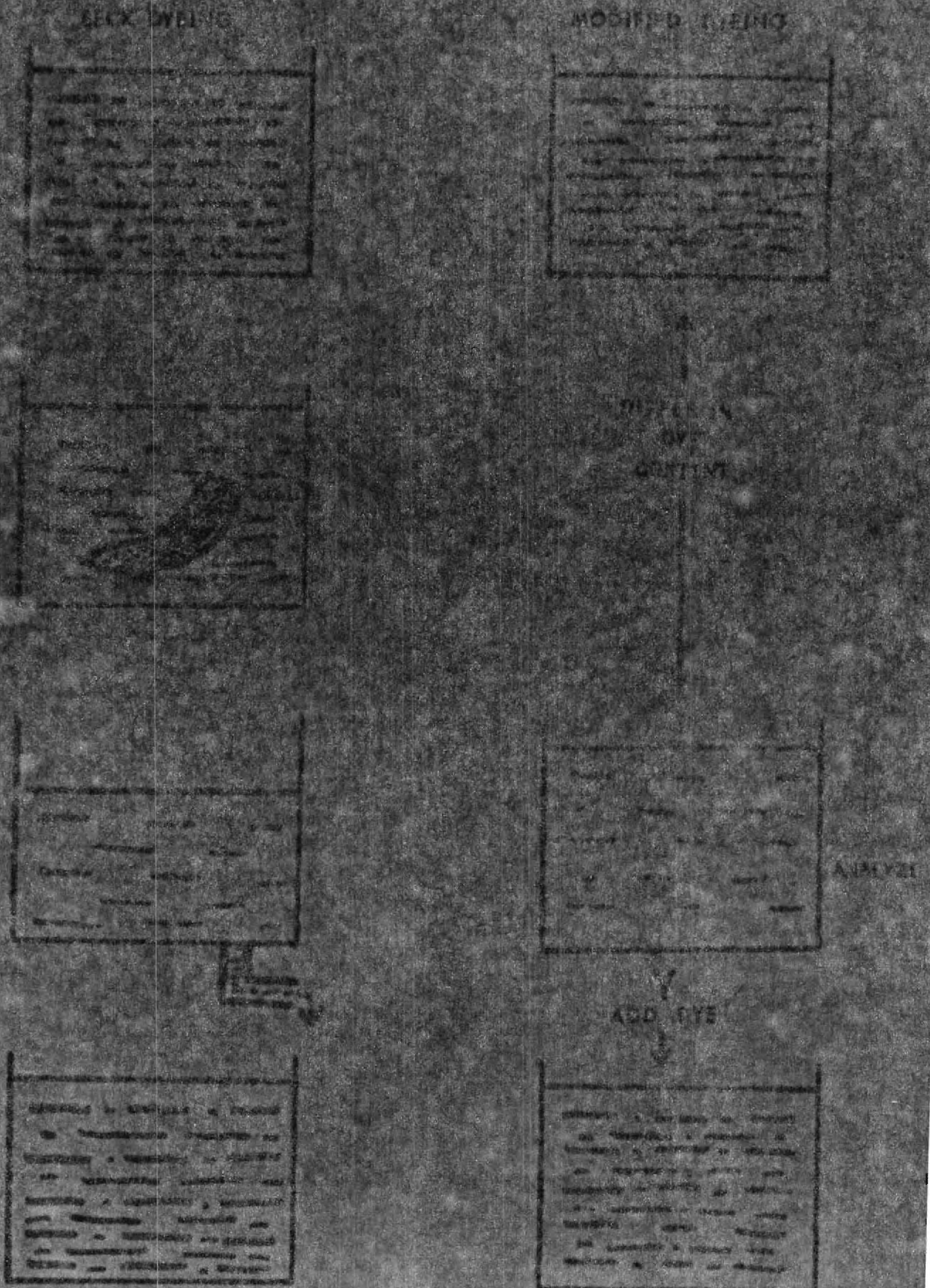


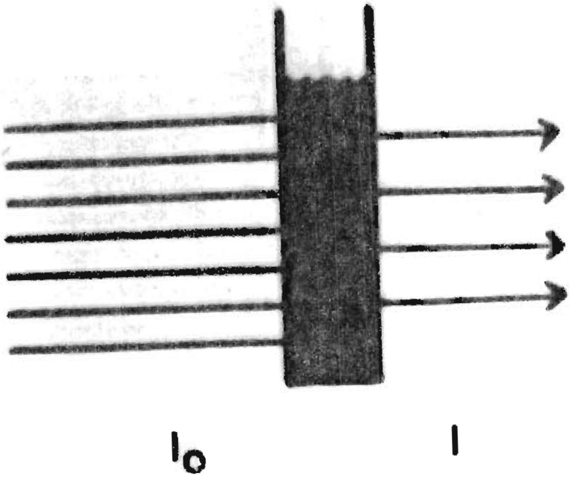




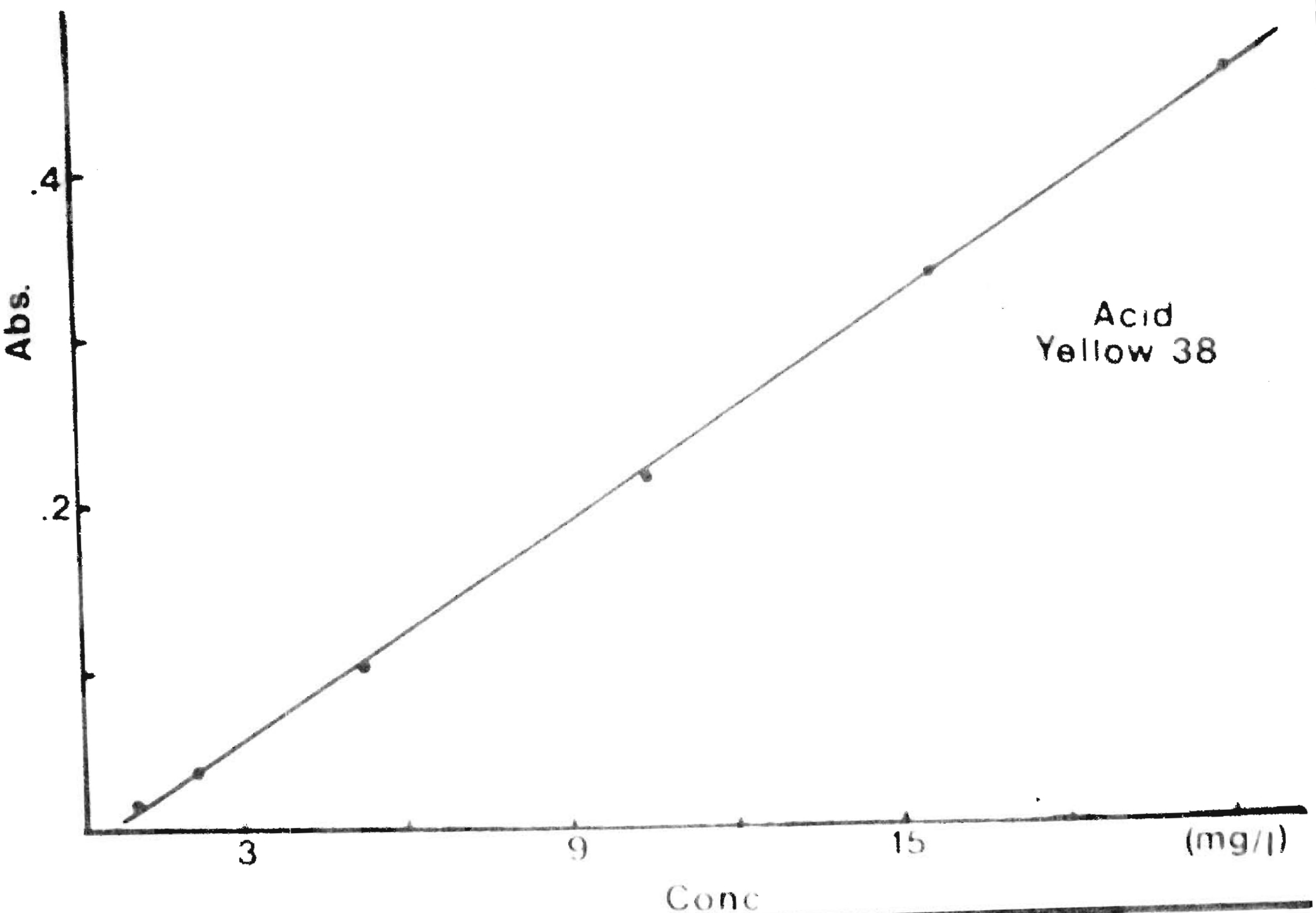


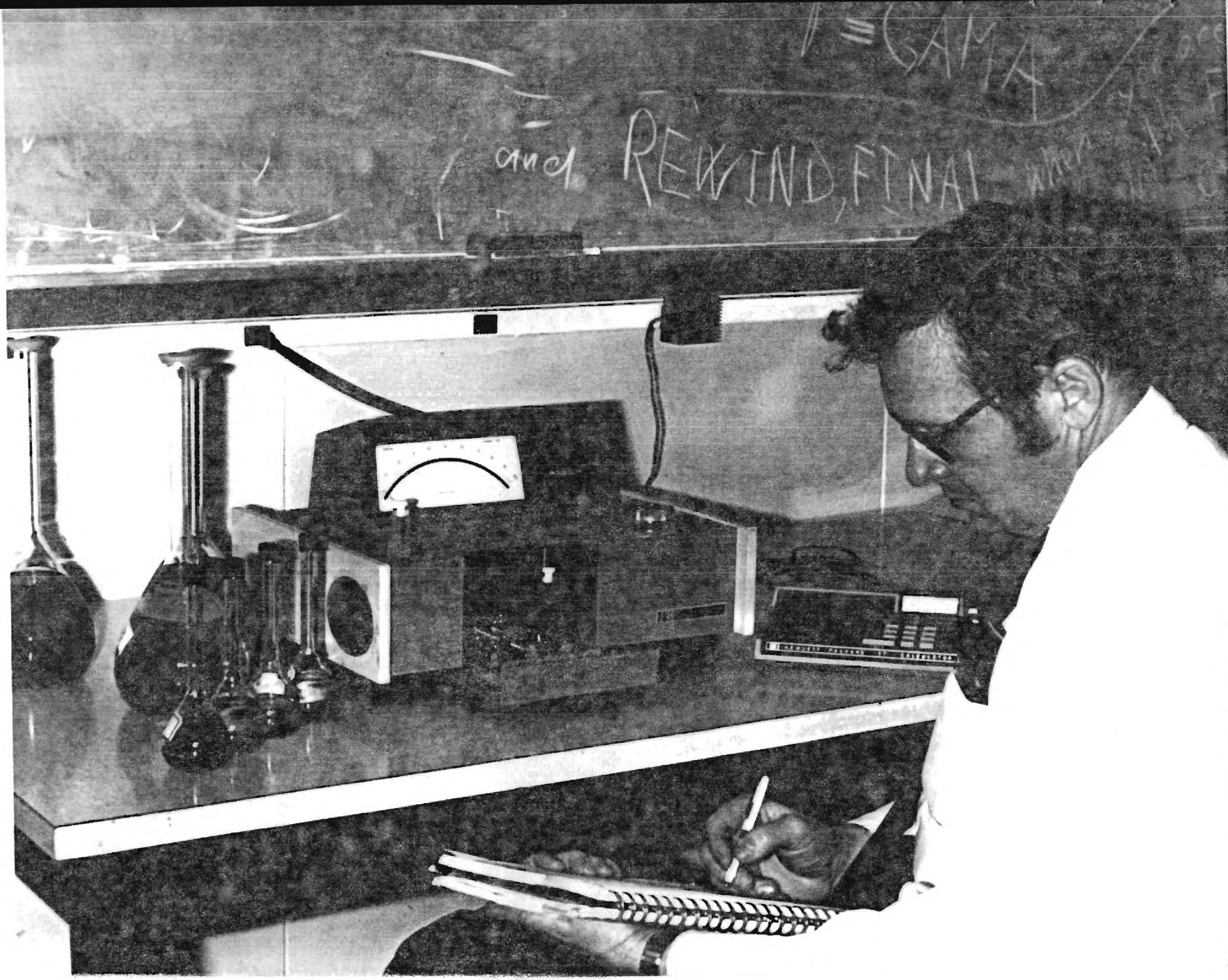
CARPET PRODUCTION

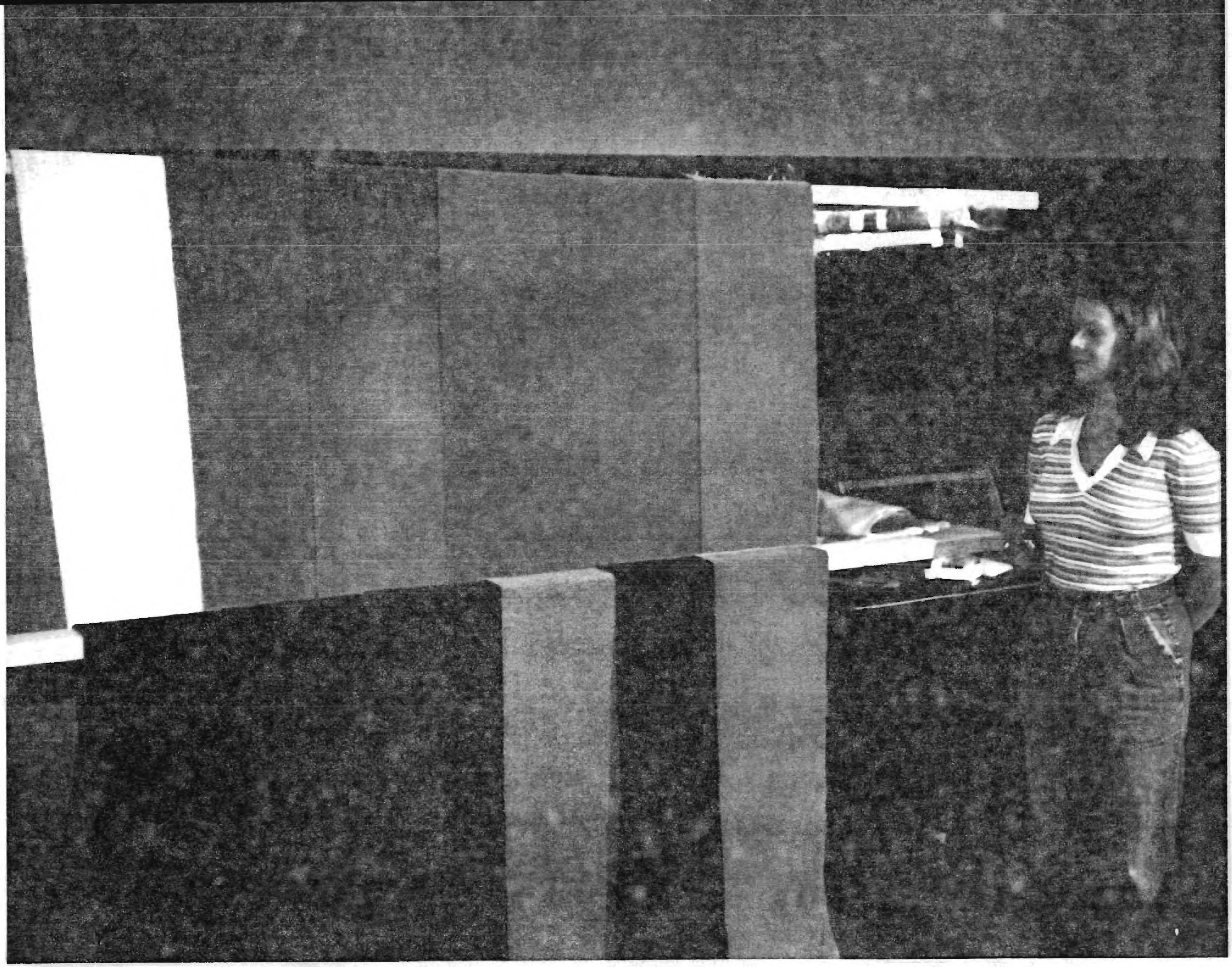

BECK DYEING
MODIFIED DYEING
ADD DYE

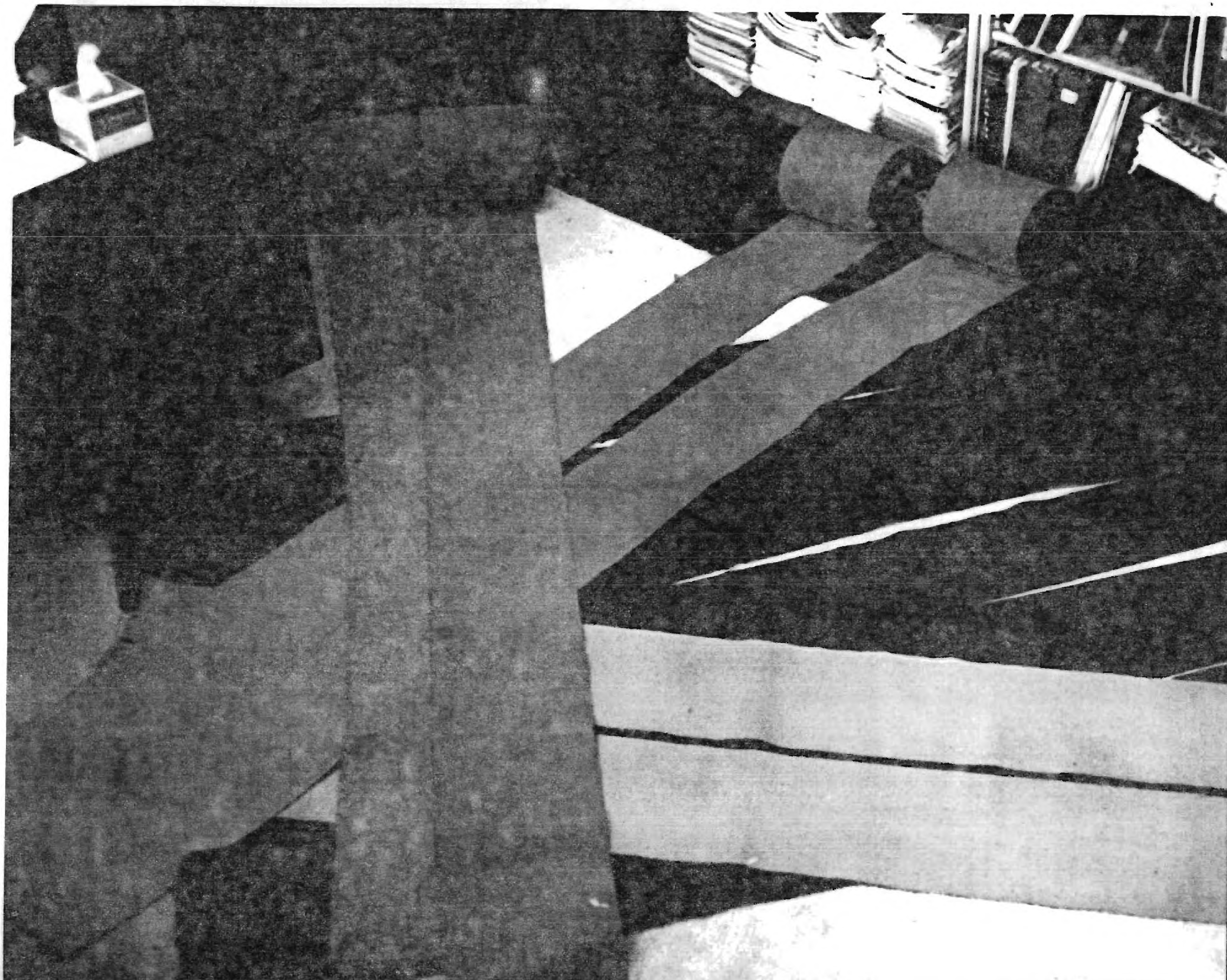


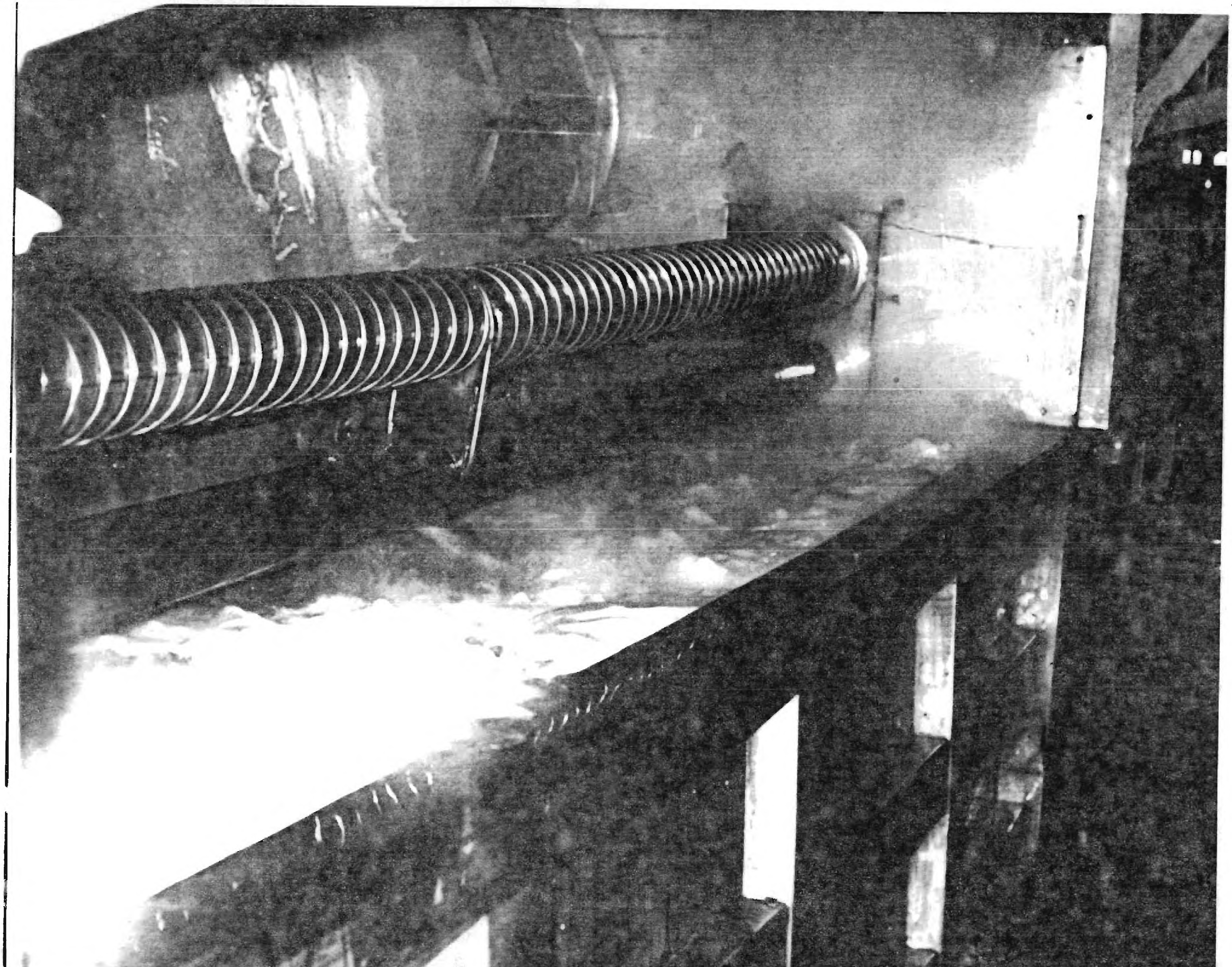
$$\log \frac{I_o}{I} = kC$$

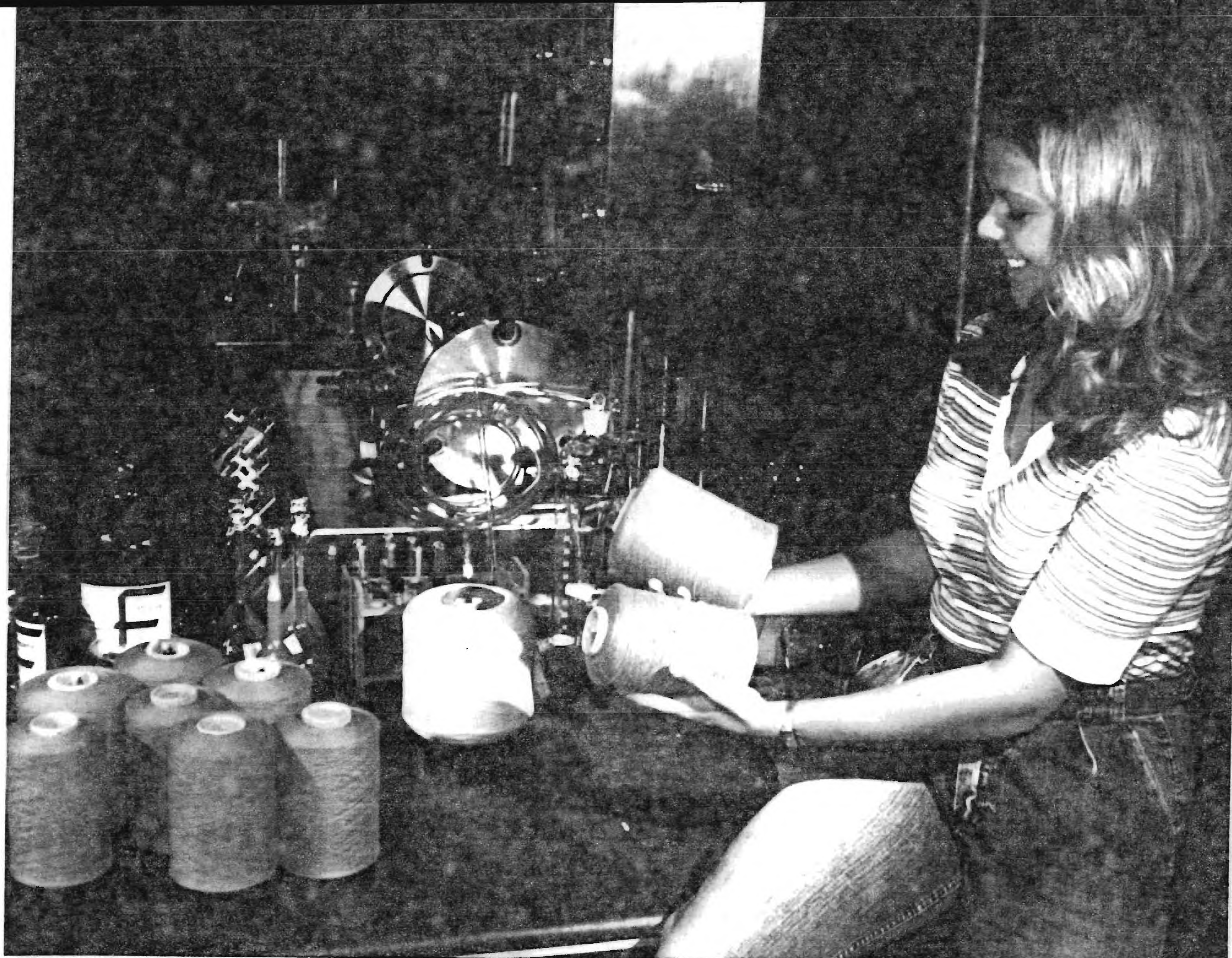



GAMA
and REWIND, FINAL








F